Lidar Observations of Atmospheric CO_2 Column during 2014 Summer Flight Campaigns

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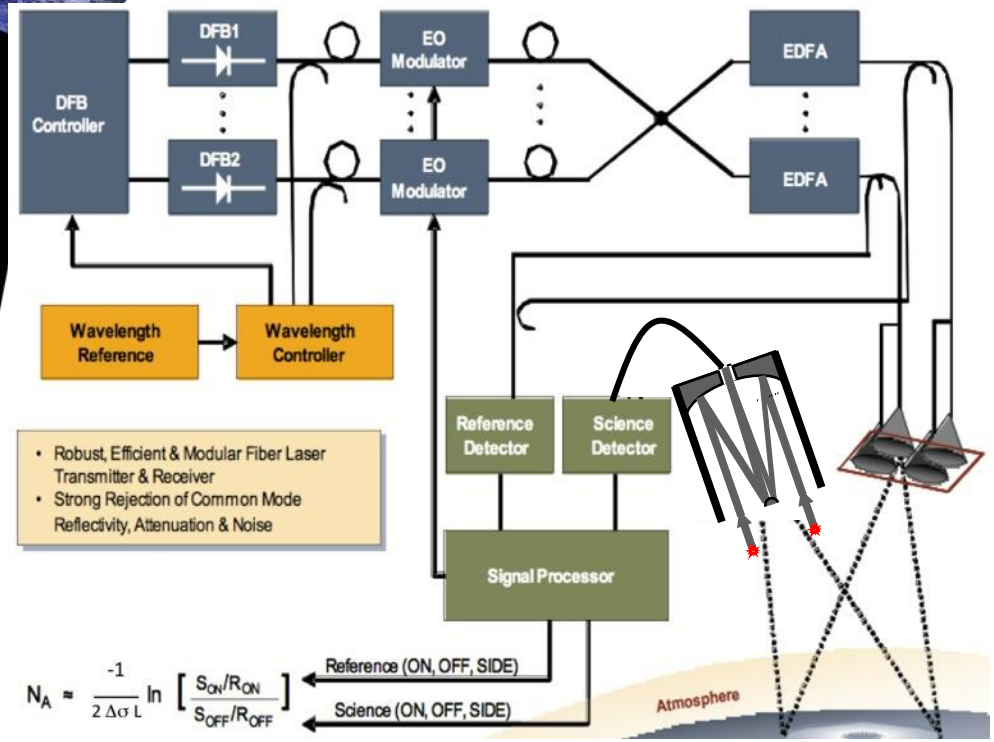
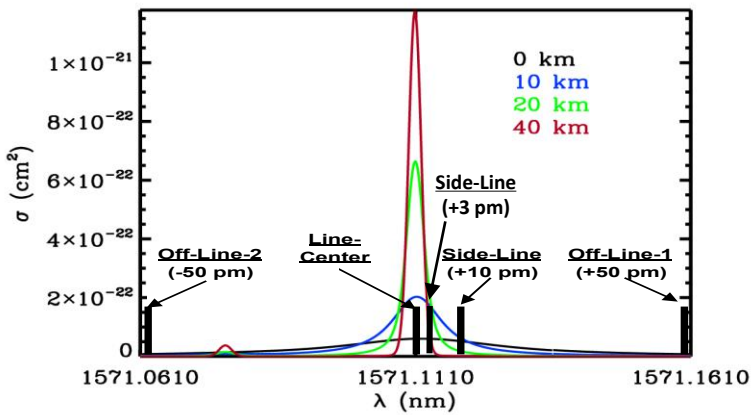
Sci. & Tech. Demonstration for space lidar missions

- **MFLL DC-8 Flight Campaign (28 July – 3 Sept)**
  - OCO-2 under flights
  - Agriculture drawdown and respiration;
  - Ocean measurements
  - Forest CO_2 measurements;
  - Urban activity
- **ACES HU-25 Flight Campaign (July 2014)**
  - Ground & flight tests in relevant environment
  - CO_2 measurements in various surface and weather conditions
  - Technology: increased power, low mass, multi-beam operation
- **Measurement Results**
  - CO_2 column variability: different environmental conditions
  - Comparison with in situ derived results
- **Summary**

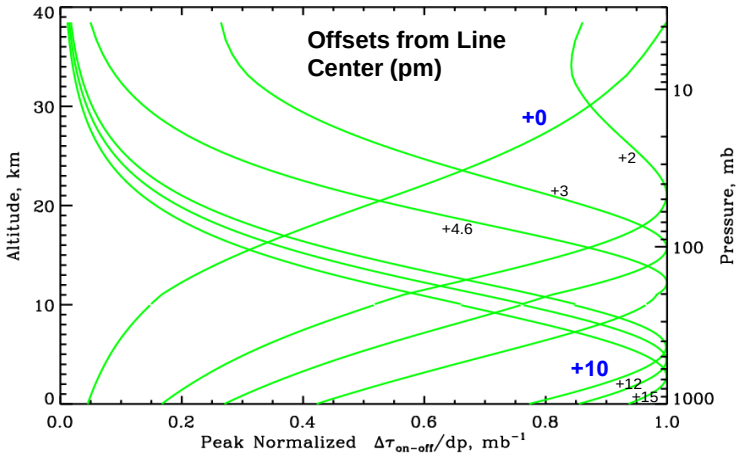
CO_2 Measurement Architecture
IM-CW Laser Absorption Lidar



- Simultaneously transmits λ_{on} and λ_{off} reducing noise from the atmosphere and eliminating surface reflectance variations.
- Approach is independent of the system wavelength and allows simultaneous CO_2 & O_2 (1.26 μm) number density measurements, combining them to derive XCO_2.



Weighting Functions



Airborne System Demonstration

ASCENDS CarbonHawk Experiment Simulator (ACES developed at LaRC with support from Exelis)

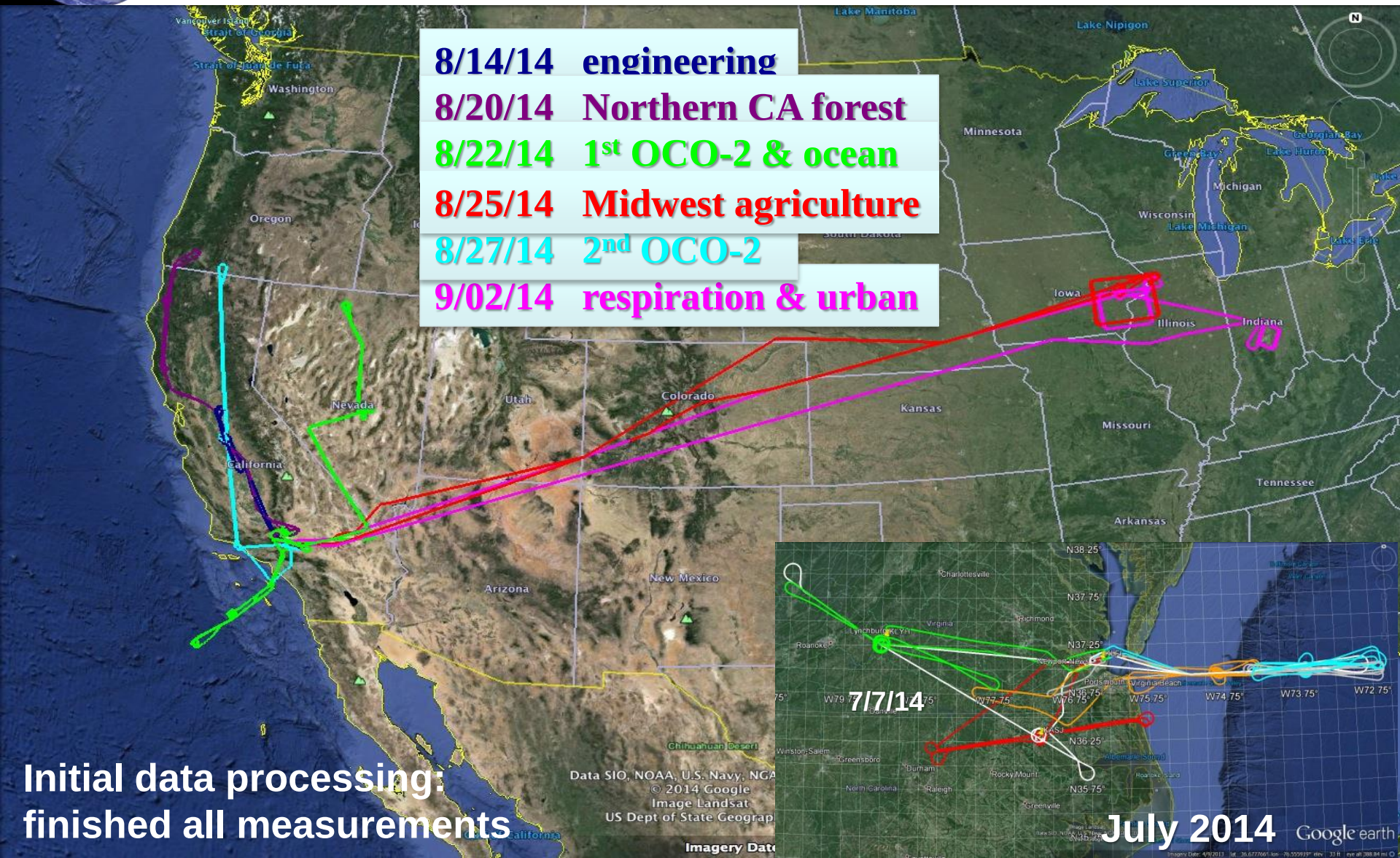
Multifunctional Fiber Laser Lidar (MFLL) (developed by Exelis in 2004 Exelis and Langley since 2005)

Instrument-aircraft integration

3×10W amplifier integration

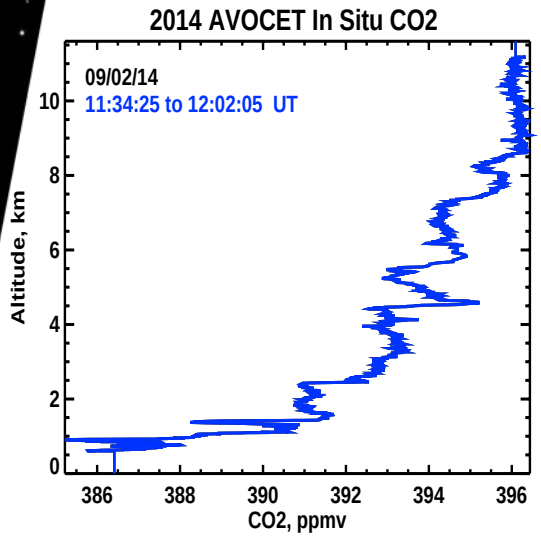
advancing key technologies for spaceborne measurements of CO_2 column mixing ratio

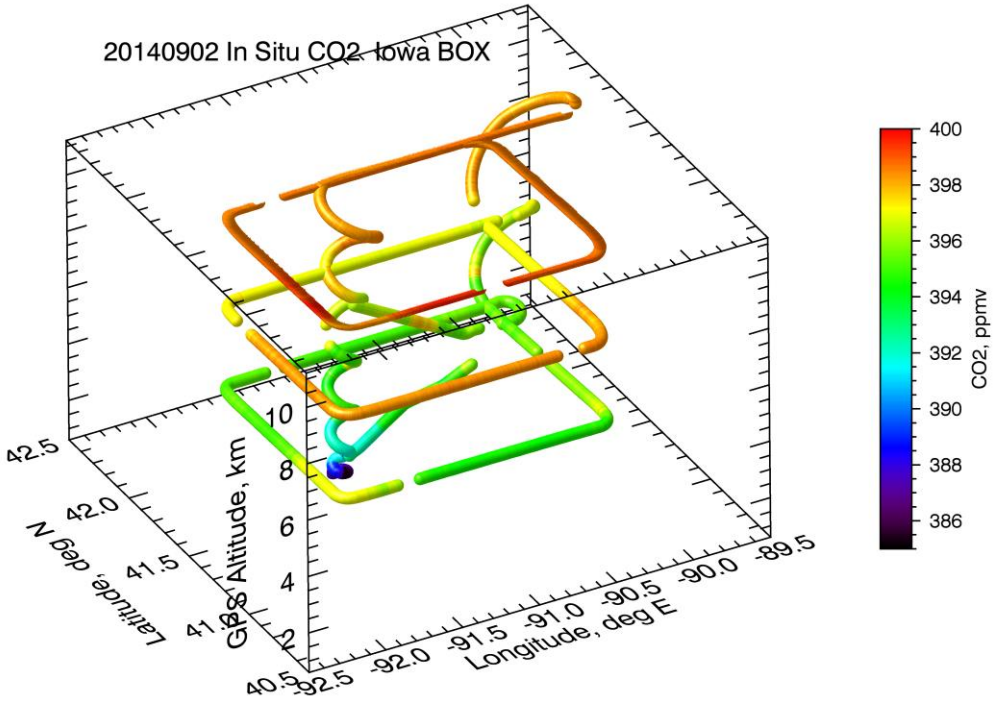
2014 ASCENDS DC-8 Campaign & ACES HU-25 Flight Test

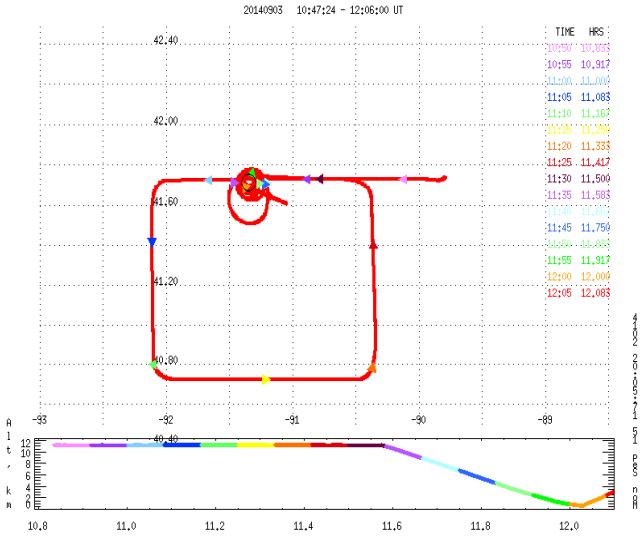


In-situ Measurements and Natural variability

(Mid-West Flight: Iowa Box; 02 Sept 2014)

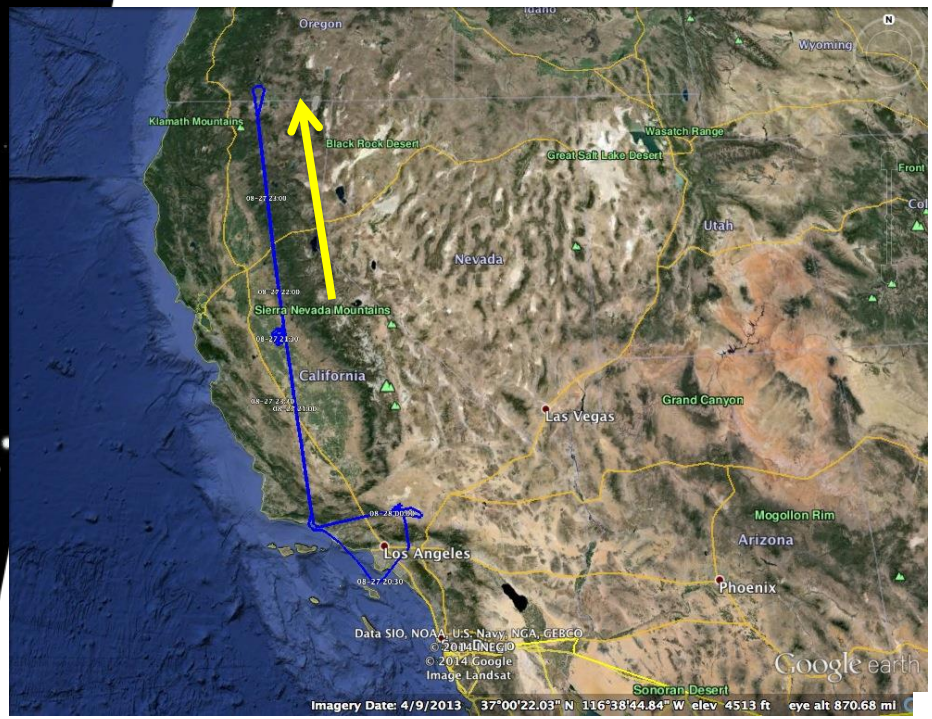






Significant spatiotemporal differences (a few ppm) found when comparing spiral with non-spiral in-situ observational data

OCO-2 Flight: 20140827



- Significant range variability observed over both short and long time scales
- Precise DAOD measurements
- Potentially used in OCO-2 validation, comparison, and evaluation

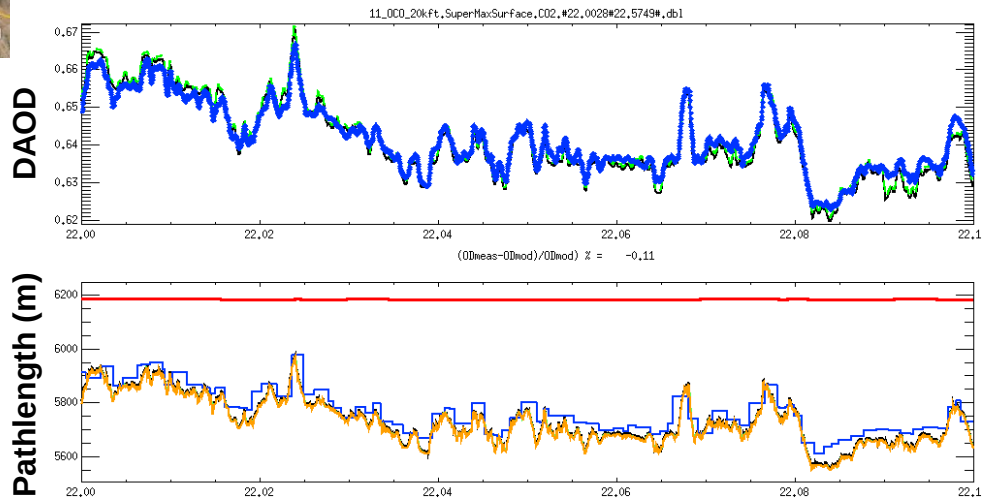
GPS altitude

GPS – Elevation database

Pseudo-noise (PN) code altimeter range

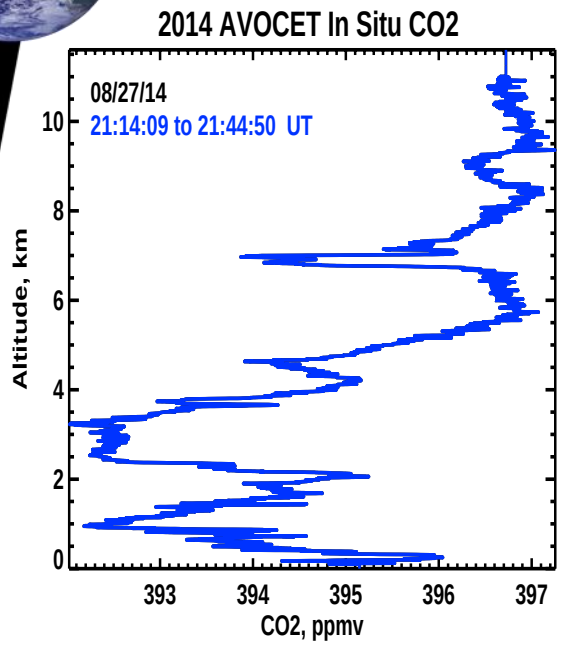
Attitude corrected PN range

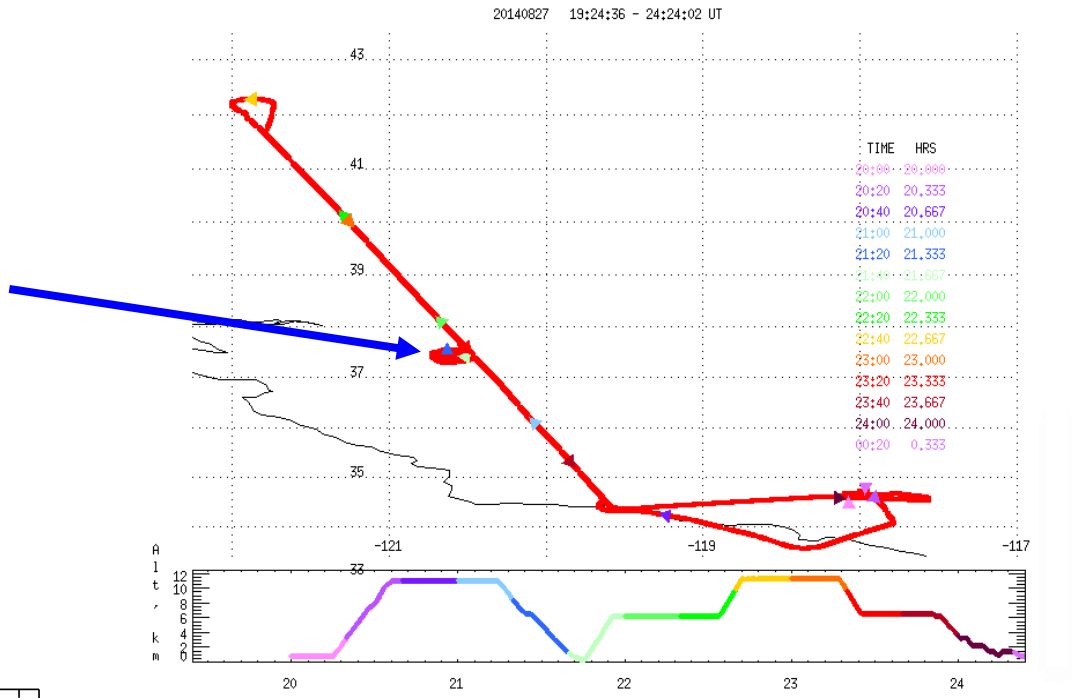
CO_2 lidar pathlength

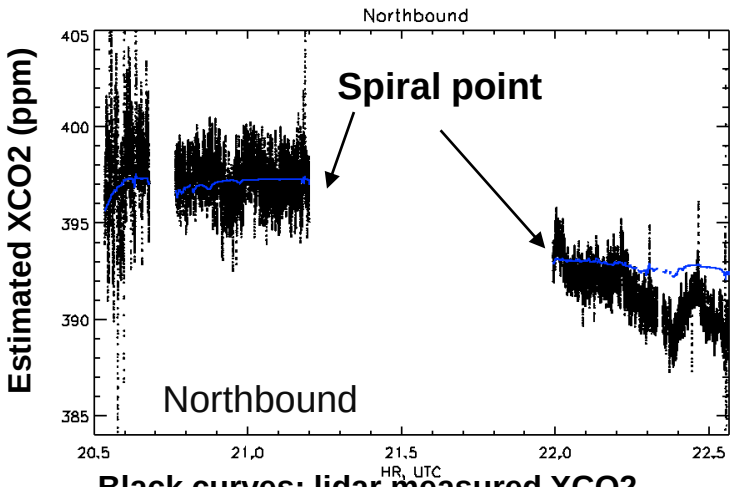


In Situ and Lidar Comparision

(MFLL OCO-2 Under Flight: 20140827)







Black curves: lidar measured XCO2

Blue curves: in-situ derived XCO2

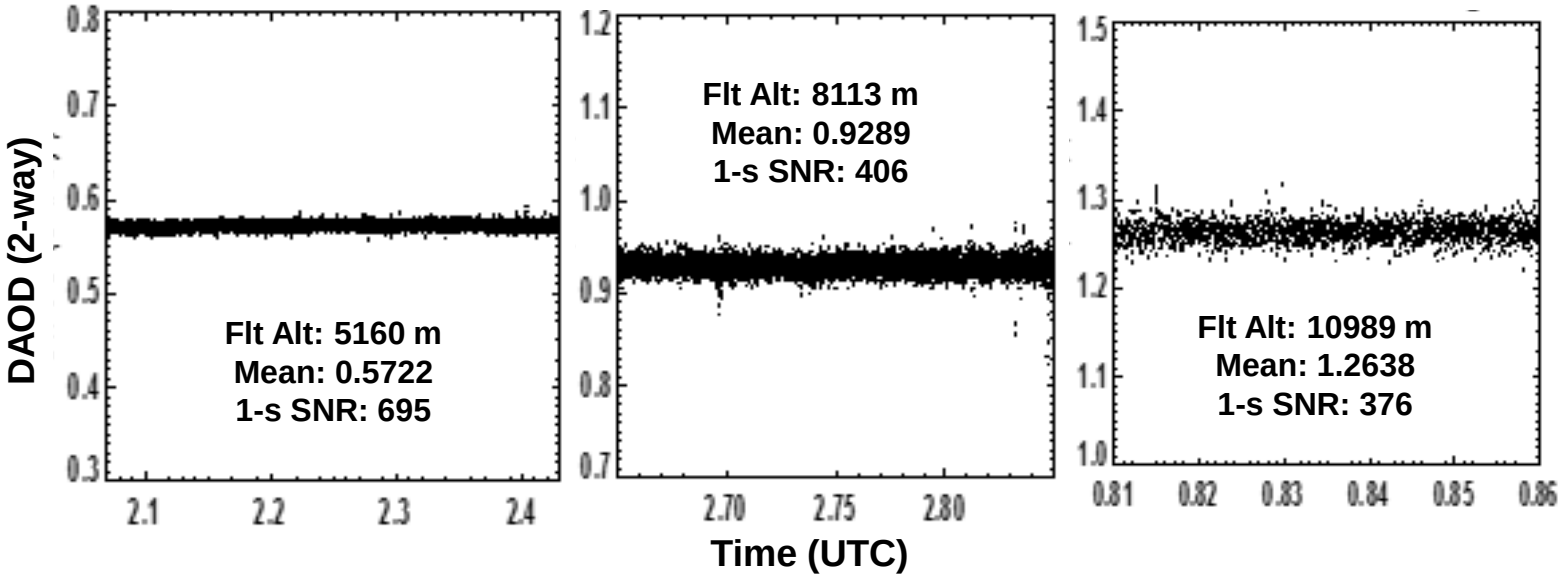
In-situ derived (or modeled) Value

- In-situ from Spiral: XCO_2, T/p/q profiles
- Radiative transfer model
- Ranging correction with lidar range data
- In-situ derived (or modeled) DAOD
- In-situ derived (or modeled) XCO_2

difference (ppm): 0.18

Ocean CO_2 Measurements

- Flight over the pacific ocean during the 2014 ASCENDS campaign demonstrates the MFLL instrument's high precision measurements over low reflectivity surfaces
- Initial results from the flight data show the CO_2 measurements are obtained in a condition close to lidar signal power shot noise limit



22 Aug 2014
MFLL flight over ocean

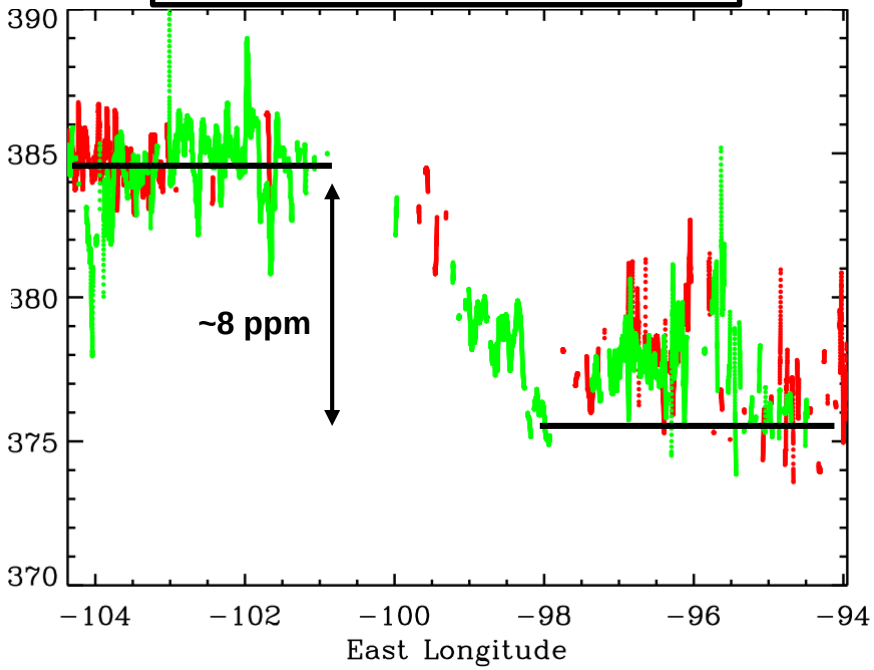
Nighttime

Agricultural CO_2 Drawdown

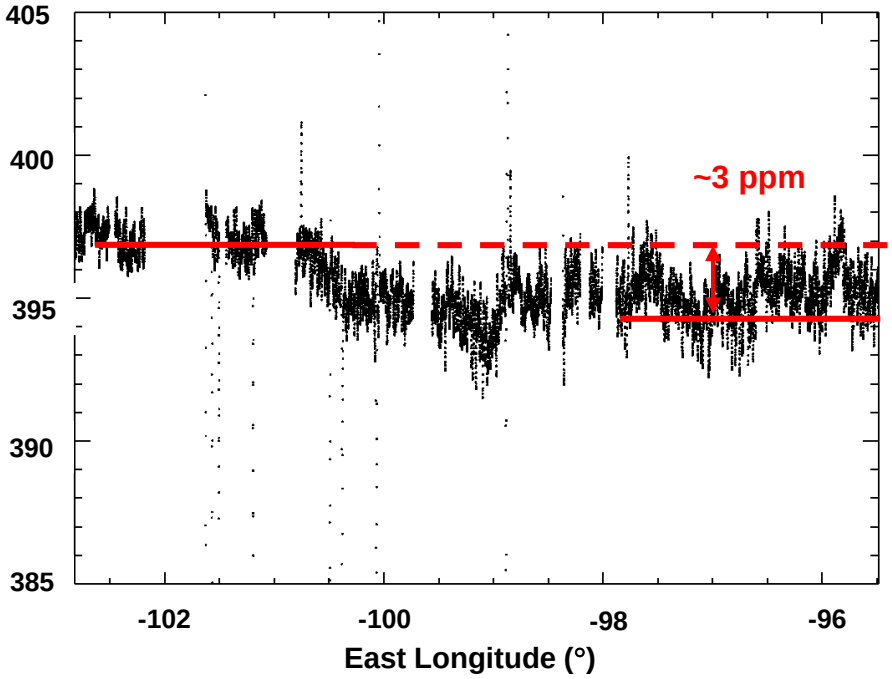
Column CO_2 measurements over Midwestern farm fields showed much larger drawdown signal in 2011 (~8 ppm) compared with measurements in 2014 (~3 ppm)

- **Resulting from differences in meteorological states and phases of growing season**

2011 Midwest Flights
Flight 6, 10 August
Flight 7, 11 August

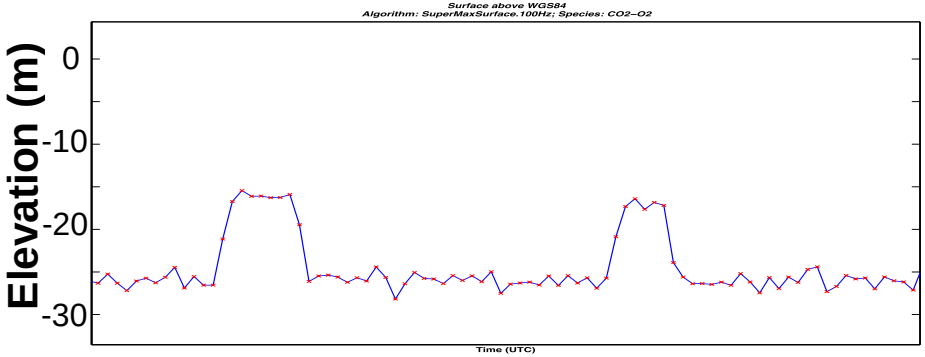


25 August 2014 Midwest Flight



Ranging over Hampton Roads (ACES in June 2014)

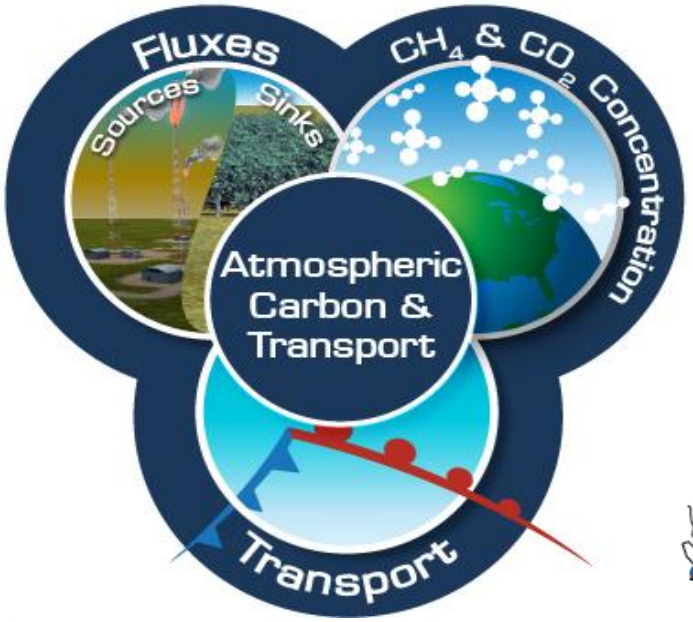
Chesapeake Bay Bridge



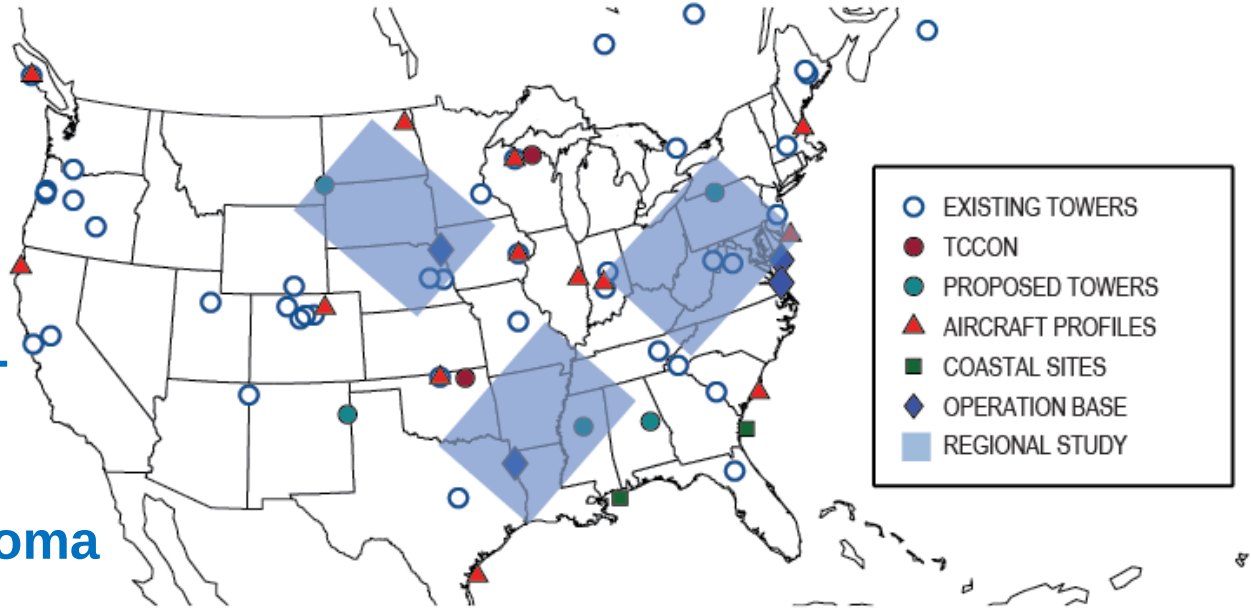
Summary

- Flight campaigns of summer 2014 provide excellent opportunity for the evaluations not only on lidar technology development but also on CO_2 variations at different, especially small, scales.
- Laser absorption lidar at 1.57μm with ranging-encoded IM provides advanced capability in cloud/aerosol discriminations.
- IM-CW lidar has demonstrated the capabilities of precise CO_2 measurements through the airborne flight campaigns under variety of environment conditions. Over land, clear-sky CO_2 measurement precision within 1-s integration is within 1 ppm while mean bias is much smaller.
- Ranging uncertainties are shown to be below sub-meter level.
- Analysis shows that current IM-CW lidar approach will meet space CO_2 observation requirements and provide precise CO_2 measurements for carbon transport, sink and source studies.

Atmospheric Carbon & Transport (ACT) – America



The ACT-America suborbital mission addresses the three primary sources of uncertainty in atmospheric inversions: atmospheric transport, sources and sinks of carbon, and atmospheric concentration measurements.



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DOE Oak Ridge, U Oklahoma
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